Factors Affecting Moisture-Storage Efficiency of Dryfarming Areas in the Great Plains

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Factors Affecting Moisture-Storage Efficiency of Dryfarming Areas in the Great Plains

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PURPOSE AND EXTENT OF STUDY

The purpose of this study was to evaluate certain naturally occurring and farm operational factors affecting moisture-storage efficiency under dryfarming conditions in the Great Plains.

Data were collected for 5 crop years, 1947–51, in 44 scattered soil conservation districts in the Great Plains. They comprise 17,680 individual field records during a period of generally more-than-average rainfall. However, seasonal variations of moisture supplies from place to place and from year to year were large enough to produce results ranging from complete failure to bumper crops. The data covered by the time interval in this study are sufficiently representative of climatic conditions in the Great Plains that they could be used for other years in this region in interpreting similar problems.

METHODS AND FACTORS STUDIED

Normal differences in farming methods among farmers provided wide ranges of data for the factors selected for study, although a farmer was not requested to modify his practices for purposes of comparison.

The selection of areas to be sampled was left to the discretion of personnel in charge of sampling in a given district. It was hoped that this procedure would result in an accurate picture of average agricultural conditions of representative districts. But farmers who did not have a detailed soil survey of their property or were not willing to cooperate in supplying desired information were excluded from the study.

However, within the limitations and designation of selected districts agreed upon by State agricultural experiment stations and research committees of the three Soil Conservation Service regional offices, it is believed that a very good cross section of semiarid agriculture of the Great Plains was obtained.

Locations of the districts under consideration are shown in figure 1. A description of the sample districts is outlined in table 1.

Records of all the variables studied, both natural and operational, were obtained by trained field

Table 1.—*Description of soil conservation districts coverd in the study*

Area, soil conservation district, and State	Predominating soil textures	Soil color range	Field records [1]
			Number
Northern spring wheat area:			
Two Creeks, N. Dak	Hard lands	Black	187
Hamill, S. Dak	do	do	561
Clearfield, S. Dak	Sandy lands	do	414
American Creek, S. Dak	Hard lands	do	500
Buffalo-Brule, S. Dak	do	do	674
Redfield, S. Dak	do	do	663
Beadle, S. Dak	do	do	540
Reserve, Mont	Wide range	Dark brown	246
Culbertson, Mont	do	do	379
Little Muddy, N. Dak	do	do	195
Arnegard, N. Dak	do	do	200
Haakon, S. Dak	Hard lands	do	517
Mona Andes, Mont	Wide range	Brown	208
Central winter wheat area:			
Red Willow, Nebr	Hard lands	Black	397
Decatur, Kans	do	do	319
Ellis, Kans	Wide range	do	442
Chase, Nebr	Sandy lands	Dark brown	409
Peetz, Colo	Wide range	do	467
Haxtun-Yuma, Colo	Sandy lands	do	216
Plainview-Smoky Hill, Colo.	Hard lands	do	1,014
Sherman, Kans	do	do	608
Scott, Kans	Wide range	do	368
Horse-Rush, Colo	do	Brown	467
Cheyenne, Colo	do	do	395
Southern winter wheat area:			
Canadian, N. Mex	Sandy lands	do	380
Quay, N. Mex	Wide range	do	328
Curry, N. Mex	do	do	836
Texas, Okla	Hard lands	do	312
Beaver, Okla	Wide range	do	348
Ochiltree, Tex	do	do	511
Lipscomb, Tex	do	do	326
Deaf Smith, Tex	Hard lands	do	255
Castro, Tex	do	do	247
Briscoe, Tex	do	do	214
Hale, Tex	do	do	294
Floyd, Tex	do	do	322
Dewey, Okla	Wide range	Reddish brown	354
Ellis, Okla	do	Brown	355
Duck Creek, Tex	do	Reddish brown	195
Two Buttes-Bent, Colo	do	Light brown	330
West Baca, Colo	do	do	332
Northeastern, N. Mex	do	do	321
Mesa-Colfax, N. Mex	do	do	523
Roosevelt, N. Mex	Sandy lands	do	494

[1] Each record consists of a complete set of data for 1 field for 1 crop season beginning with the harvest of the previous crop.

[1] The Oklahoma Agricultural Experiment Station analyzed the statistical data for the report; the State agricultural experiment stations of Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, and Texas cooperated in the planning of the field work of this study. The Soil Conservation Service technicians personally responsible for the collection of field data at different stages of the project were Merritt E. Anderson, Chamberlain, S. Dak.; Roy V. Bailey, Perryton, Tex.; Ellis M. Baker, Oberlin, Kans.; J. D. Chapman, Las Cruces, N. Mex.; David K. Daubert, Littleton, Colo.; Alvin H. Jackson, Silverton, Tex.; Rannell R. Jones, Clovis, N. Mex.; Vincent R. Killerlain, Burlington, Colo.; Bruno Klinger, Fort Collins, Colo.; Oliver R. Nuzum, Osborne, Kans.; Olmon W. Sweat, Plainview, Tex.; William R. White, Clovis, N. Mex.; and George Truman Williams, Stanley, N. Dak.

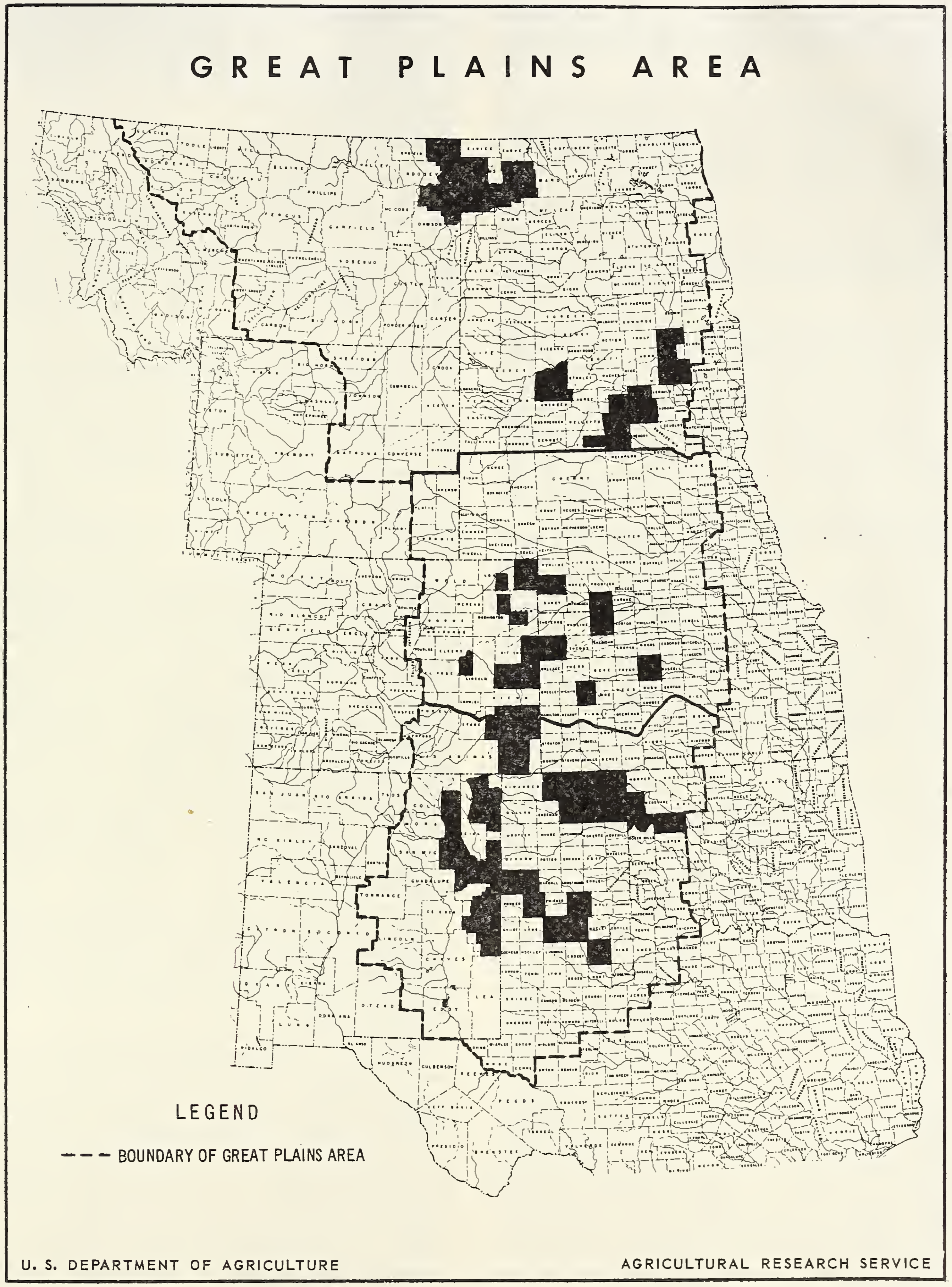

FIGURE 1.—Soil conservation districts in the northern spring wheat area, the central winter wheat area, and the southern winter wheat area of the Great Plains in which factors were evaluated for soil-moisture efficiency.

personnel. Results of various farm practices or natural factors were obtained under average farm conditions and as a part of the farmers' regular routines.

An attempt was made to include all data that would contribute to a measure of moisture-storage efficiency under dryland farming practices. Twenty-four such variables were recorded in this study, 10 of which are evaluated herein. Records collected included total amount and character of rainfall, temperature, soil characteristics (for instance, texture, slope, color), previous crop, residues, weeds, length of period between crops, tillage, and other miscellaneous soil, crop, and climatic data.

For purposes of local application of findings, the Great Plains was divided into three broad areas: The northern spring wheat area; the central winter wheat area; and the southern winter wheat area. Within these areas data of individual districts may be selected to apply specifically to particular soil and climatic combinations found locally in the States represented. For that purpose, each district was analyzed separately and its identity preserved throughout the study.

Regardless of types of crops grown and order of their sequence, an idle period between crops was used for soil-moisture accumulation, beginning with a relatively dry start (at harvest of previous crop) and continuing free of any draft by a growing crop until the field was adjudged by the operator to be ready for the next planting. Degree of success in storing soil moisture was measured at time of planting the oncoming crop by recording field observations of depth of moisture penetration.

The efficiency of rainfall in increasing soil-stored available moisture for the oncoming crop is determined by physical conditions surrounding reception of rainfall; not all conditions were accounted for in this experiment. Furthermore, once the moisture has been safely deposited within the root zone of crops, its usefulness in production can be changed drastically by other factors inherent in agriculture.

The index of moisture-storage efficiency used in this study was derived as follows: Rainfall was compiled for the period from harvest of previous crop to planting of ensuing crop. Accumulated depth-in-inches-of-moisture penetration observed at planting time was divided by inches of rainfall received to give a figure representing inches of penetration per inch of rainfall. Total penetration may be considered as a rough measure of quantity of available moisture accumulated for use by the oncoming crop. Inches of wetted soil per inch of rainfall is a measure of the efficiency of moisture storage for that particular time and place. In this report the term "moisture efficiency" will refer to this index number. Moisture efficiency is of vital interest to dryland farmers of the Great Plains, especially insofar as they are able thereby to reduce drought hazard.

All conditions and combinations of conditions that tend to increase or decrease moisture efficiency may be grouped into two classes: (1) Fixed or natural factors normally beyond the control of farmers; and (2) operational factors under control of farmers.

Variations in seasonal conditions, such as temperature and amount and character of rainfall, are considered natural factors and are beyond the control of farmers, except to the extent that they can choose crop sequences which place periods between crops at particular seasons of the year. Even then, seasonal variations remain a factor largely beyond control. Often a small workable latitude exists between early- and late-seeding dates.

Farmers can control their cropping operations by deciding which tract of land will be put in cultivation, what location will be chosen, or even in what section of the country they will settle in the first place. Once these initial commitments are made, changes in land character and climate become less dependent on the farmers' decisions and more on natural variations. It is only practical that farmers accept natural variations as they occur and attempt to deal with problems of moisture efficiency through operational means.

Three factors appear to underlie many of the differences observed in soil-moisture efficiency in the Great Plains: (1) The climatic differences that result in an increase in topsoil organic matter, which doubles twice from southeastern New Mexico to northeastern Montana; (2) the crop sequences in the central and southern areas, where higher summer temperatures in the preplanting period affect soil-moisture efficiency for fall-sown crops; and (3) the farmers' choice of hard lands for wheat and of sandy lands for row crops in the extreme southwestern part of the Plains. This selection of soils appears to be more pronounced progressing from east to west in the southern Great Plains, which is also from lower to higher elevations.

The oncoming crop is of no consequence, except to indicate the time of year when the end of initial soil-moisture storage occurred. Normal planting dates for specific crops are well known by those familiar with the agriculture of the various areas listed in table 2.

Simple correlation analyses for five sample districts in each of the northern, central, and southern Plains areas were computed, relating the 24 measured factors listed in appendix (table 3) to moisture-storage efficiency. Simple correlation coefficients thus obtained indicated that only 10 of the 24 variables assessed consistently related significantly to moisture-storage efficiency. Therefore, data for only these 10 factors are presented and discussed in this report. Simple correlation and multiple regression analyses were computed for these 10 factors and serve as the basis of interpretation in this report. These 10

Table 2.—*Comparison of wheat and row-crop preparatory periods for moisture-storage efficiency in different parts of the Great Plains, 1946–51*

Soil and area [1]	Moisture penetration per inch of rainfall preparatory to—		Ratio of wheat efficiency to that of summer row crops
	Corn or sorghum	Wheat	
	Inches	*Inches*	
Black soils, northern North Dakota	3. 54	4. 18	118
Black soils, eastern South Dakota	3. 33	3. 42	103
Dark-brown soils, northwestern North Dakota and northeastern Montana	6. 69	6. 15	92
Dark-brown soils, North Dakota and South Dakota	2. 84	3. 35	118
Dark-brown soils, eastern Montana	5. 05	5. 35	106
Black soils, central Kansas	2. 64	4. 00	151
Dark-brown soils, northeastern Colorado and western Kansas	3. 23	3. 08	95
Dark-brown soils, northwestern Kansas and northwestern Nebraska	3. 39	3. 65	108
Brown soils, eastern Colorado	3. 17	2. 56	81
Brown soils, Panhandle of Oklahoma and Texas	3. 32	3. 22	97
Brown soils, eastern New Mexico and western Texas	6. 23	3. 25	52
Reddish-brown soils, Oklahoma and Texas	2. 81	2. 75	98
Light-brown soils, northeastern New Mexico and southeastern Colorado	5. 51	3. 11	56
Light-brown soils, southeastern New Mexico	6. 00	3. 58	59
Average:			
Black soils			124
Dark-brown soils			104
Reddish-brown soils			98
Brown soils			77
Light-brown soils			57

[1] Color of soil deepens from south to north and from west to east and represents an increase in topsoil organic matter; i.e., soils are much darker in northern and eastern parts of the Great Plains.

factors and methods of obtaining the data are listed below.

Total rainfall (*TR*) was compiled separately for the preparatory period of each field, using the record of the nearest rain gage. Average distance of fields from a rain gage was approximately 1½ miles, although a substantial number of rainfall records were made on the actual tract under observation.

To obtain this close coverage of areas studied, 825 new rain gage stations were established by the Soil Conservation Service in addition to the 167 stations that were already publishing records through the U.S. Weather Bureau. In many instances, the average annual rainfall figures obtained for 1946–51 were several inches more than the longtime average recorded for the district. Moisture-efficiency variations common to parts of the Great Plains are given in table 2.

Owing to the wide variation in length of the period between crops, not total rainfall but mean rainfall per week (*WR*) was used as an indication of light or heavy precipitation. *WR* equals total rainfall (*TR*) of the idle period between crops divided by the number of weeks covered.

A further look at the character of rainfall was taken by observing amounts per rainy day (*I*), or average intensity. Traces were ignored. The amounts of rainfall per rainy day distinguished very well between the slow intermittent rain that extended over a number of days, several of which contributed only a few hundredths of an inch, and the quick heavy shower that came in a few hours' time.

Another natural factor, mean temperature (*T*), was obtained from the nearest Weather Bureau record for each field for the exact time between harvest of previous crop and the seeding of the next crop. All records were coded in 10° F. intervals.

Mean temperatures in the forties (40° to 49° F.) occurred throughout the Great Plains but generally were limited to intervals between fall harvest and spring planting. Temperature means for period between crops reached as high as the sixties (60° to 69°) throughout the Plains, and some were in the seventies (70° to 79°) for the central and southern areas. In the northern area the 60° means were associated with a period between crops that involved summer fallowing. In the central and southern areas, 70° means usually involved only a very short period between summer harvest of small grain and early fall sowing of winter wheat.

The remaining natural factors considered in this study were inherent to the fields—land slope (*S*) and surface soil texture (*ST*).

Soils were roughly classified by a code that was based on increasing amounts of sand in the physical composition of surface soil. Descriptive names of the seven classes recognized are as follows: Clay loam, silty clay loam, silt loam, fine sandy loam, sandy loam, loamy sand, and sand.

Ranges of slopes were from 1 to 7 percent. The slopes cultivated were generally steeper in the northern Plains districts.

Matters of soil, water, and crop management practices are largely subject to operational control. Extreme ranges in farm practices were quite frequent in this study, and often the range from poor to good practices was more extreme than those ranges found for natural conditions. For example, every degree of weed control can be found from no control to complete control. Weeds were controlled during this study solely by tillage. Amount of soil stirred during the period between crops may be determined largely by extent and frequency of weed infestation, ease of control, and length of the idle period between crops. It is even possible that some farmers tilled the soil too much.

A record was kept of kind and frequency of tillage carried out between harvest and planting of the next crop on each field. A special study of tillage methods indicated that gross amount of tillage, expressed as total acre-inches of soil stirred, was probably more significant than type of implement used. Hence, acre-inches of soil stirred is the variable selected for this study and is called the tillage index (*D*). The tillage index was obtained by adding together depth of all tillage operations performed during the prepara-

tory period. Average depths of soil stirred estimated for various operations were: Plowing, 6 inches; half-plowing or listing, 3; disking, 3; chiseling, 4; and cultivating, 3.

Type of tillage, however, involves water conservation practices and stubble mulching. Degree of water conservation practice (C), including the combination of two or more methods on the land, must surely have a measurable effect on moisture efficiency if it is at all effective in its designated purpose.

Code values originally estimated from experimental results of separate practices were used singly and in combination to rate supposed intensity of conservation practices. Stubble mulch rated 1; stripcropping, 2; contour tillage, 2; stubble left standing through winter, 3; terracing, 3; terracing and contour tillage, 4; stalks left standing through winter, 5; supplemental irrigation with diverted water, 5; and freshly broken sod, 5.

Results of stubble mulch practices (M) that persisted, if any, at the end of the preparatory period were evaluated by the following code: Stubble burned, 0; little or no crop residues left on surface, 1; scant amounts left, 2; average, 3; and abundant, 4.

Weeds during the preparatory period would have the same effect as a growing crop in removing soil moisture during the storage period and thus would reduce final depth of wetted soil present at the end of the observation. Weed growth (W) during preparation was treated as a normal hazard, the same as evaporation and runoff. As coded, weeds showed a negative effect on moisture efficiency: No weeds present and no residues indicating recent growth, 1; light weed growth, 2; medium growth, 3; and heavy growth, 4.

Finally, durability of a soil-stored body of moisture was assessed from the standpoint of time elapsed during the preparatory, or accumulation, period. This period was taken normally from harvest of one crop to the seeding of the next. However, an exception was made on weedy stubble going into summer fallow; the length of preparatory period was recorded as the period between first cultivation of the stubble and planting. During this 5-year study length of preparatory periods (L) ranged from 6 to 45 weeks. Length of time elapsing between crops changed not only with the farmer's planned sequence of crops but with seasonal emergencies as well. Sometimes, planned crop plantings were not made at all; other crops or extension of fallow periods were substituted. In this phase, as in other phases of the study, what actually happened was recorded, regardless of the reason for it.

As previously indicated, simple correlation and multiple regression analyses relating the 10 measured factors to moisture-storage efficiency were completed. As generally experienced in such analyses, strong associations between many of the factors under study were noted. In many cases the degree of relationship and, in some cases, even the sign of the relationship between a given factor and moisture-storage efficiency were different for simple correlation and standard partial regression coefficients, respectively (appendix, tables 4 and 5). This is in no way surprising, in view of the anticipated associations between various factors.

In view of the above associations, the standard partial regression coefficients offered the greatest possibility for determining independent relationships between moisture-storage efficiency and any given climatic, soil, or management factor. It should be emphasized, however, that the regression equations obtained in this study are in no way intended for predictive purposes. This procedure was used simply to obtain indicated trends in relationships between given factors and moisture-storage efficiency independent of associated effects of other variables with the independent variable under study.

In interpreting the standard partial regression coefficients several considerations must be kept in mind: (1) Occasional observance or failure to observe significance may be owing to the peculiar nature of the data at hand; (2) in the case of certain variables, the range of variation encountered may be inadequate to yield significant relationships; (3) in the case of certain variables, inherent associations between variables make interpretation difficult; (4) interpretation of certain variables, notably water conservation practices and perhaps others, may be difficult owing to inherent limitations in the original basis for indexing; and (5) the multiple regression analysis assumes linear relationships, whereas true relationships are probably curvilinear in many cases. This generally tends to reduce the level of significance observed.

The above factors, although largely unavoidable, place some limitation on the interpretation of the data and must be recognized in the use of them.

The simple correlation matrices are not presented in this paper for several reasons: (1) The data would present merely some indication of trend for each of the interrelations determined and could not be considered as quantitative in view of the nature of the data taken; (2) at best, the simple correlations would merely show indicated associations between variables that have been previously analyzed and interpreted on more quantitative data by other workers; and (3) the considerable bulk of the 44 tables required to present this material is not considered justified in view of the limitations of the data. Simple correlation coefficients (r) relating moisture-storage efficiency to the 10 factors studied are given in appendix, table 4.

RESULTS

Northern Spring Wheat Area

Two Creeks District, Stanley, N. Dak.

Black fine-textured soils predominated under an average rainfall of 15.97 inches in Two Creeks District. Slopes of cultivated fields ranged between 2 and 5 percent, with an occasional field of 6 percent.

Length of preparatory period was the one outstanding factor exerting a great effect on moisture efficiency. Land slope, of lesser importance, was still highly significant in depressing moisture-storage efficiency. None of the other natural or operational factors showed statistical significance, probably owing to the high organic matter content of black soils, which was able to absorb and hold the moisture.

Hamill District, Winner, S. Dak.

Black hard land soils predominated under a rainfall of 20.44 inches in Hamill District. Most cultivated fields lay on slopes of 3 and 4 percent, although extremes of 1 to 12 percent were represented.

The most highly significant variable in determining moisture efficiency was length of preparatory period. Strongly measurable effects of water-conservation practices, volume of tillage, and variations in amount and character of rainfall were also highly significant.

Of lesser importance was soil texture, with no apparent reaction from slope, which is probably explained by a highly negative correlation between coarseness of texture and steepness of slope. Ranges of slopes represented—1 to 12 percent—were much greater than differences in soil texture, which ranged from clay loam to silt loam.

Although a large number of factors determined moisture efficiency, the operational factors had greater influence.

Clearfield District, Winner, S. Dak.

Black loam to sandy soils, under a rainfall of 21.66 inches, predominated in Clearfield District. There were more fields of 4-percent slope than any other, although 2- and 3-percent slopes occurred, with a few fields of 1 to 8 percent.

The main difference between this and Hamill District was soil texture and its consequent effect on land use. In Hamill the main crop was wheat; in Clearfield, corn.

Length of preparatory period seemed to have a stronger bearing on moisture-storage efficiency on the sandier soils. Other significant factors reacted similarly to those of the hard land area, except that emphasis shifted from water-conservation practice to stubble mulch on sandier soils.

There was no correlation between slope and texture for this soil, but sandier soils showed higher moisture-storage efficiency, regardless of slope.

American Creek District, Kennebec, S. Dak.

Black hard land soils predominated in American Creek District under an average rainfall of 17.96 inches. The most common slope was 4 percent, with a range from 1 to 7 percent. Cultivated lands were used mainly for small grains with a few scattered fields of corn.

All five natural factors showed a significant relation to moisture-storage efficiency. Temperature was positively related, whereas average amount of weekly rainfall, size of rain, coarseness of soil texture, and steepness of slope were all negatively related. Weed growth and lengthening of preparatory period were negatively related to soil-moisture efficiency.

Buffalo-Brule District, Chamberlain, S. Dak.

Medium- to fine-textured black soils, lying on slopes of 1 to 4 percent under a rainfall of 22.28 inches, characterized cultivated lands of the Buffalo-Brule District. More fields had a slope of 4 percent than all other districts observed.

Nine factors were significant in determining moisture efficiency, although none stood out prominently. Total influence of farming practices decidedly outweighed that of natural factors. Occurrence of excess moisture reduced storage efficiency. This is the northernmost district, with cooler seasons that favor moisture efficiency to a significant extent. The more receptive soils lay on the steeper slopes.

Redfield District, Redfield, S. Dak.

Black soils of medium to fine texture lay on gentle slopes of ½ to 3 percent, under a rainfall of 19.63 inches, in the Redfield District of Spink County, S. Dak.

Heavy rainfall and delayed cropping contributed most to the depressing efficiency of moisture accumulation. Substantial depressing effects were also caused by low temperatures, neglect of weed control, and fine-textured soils. Stubble mulch was beneficial. Interval between crops did not vary greatly with different crop sequences, except in the few places where summer fallow was practiced. Natural factors had a stronger influence on moisture-storage efficiency than cultural practices.

Beadle District, Huron, S. Dak.

Black soils ranged in textures from medium to moderately heavy. Slopes varied little from the 2-percent average, but a few extremes ranging from ½ to 4 percent were noted. Rainfall at Huron averaged 20.43 inches.

Operational factors of water conservation practice, stubble mulch, tillage volume, and close crop sequence showed highly significant relations to soil moisture. Weed control was a difficult prob-

lem; however, only the preparatory season of 1947–48 (1 year out of 5) got out of hand generally. Weeds measurably decreased moisture-storage efficiency. Summer fallow was not practiced extensively or regularly.

Variation in slope was not enough to be strongly felt, but medium-textured soils showed a distinct advantage over heavier soils. Effects of temperature and excessive rates of rainfall were in line with observations noted in the northern spring wheat belt generally.

Reserve District, Plentywood, Mont.

Dark-brown soils of a wide range of textures, heavy clay loam to sandy loam, lay on slopes of 2½ to 4½ percent in this far northern district, where rainfall averaged 14.41 inches.

Frequent tillage and a close sequence of crops favored moisture efficiency. None of the other operational factors showed significance. Heavier moisture supplies than could be most effectively utilized were indicated by a highly significant negative regression coefficient for weekly rate of precipitation. Other soil and climatic factors did not vary enough to show significant relations.

Culbertson District, Culbertson, Mont.

Dark-brown soils, ranging in texture from silty clay loam to sandy loam, lay on 2- to 6-percent slopes under an 11.41-inch rainfall in Culbertson area of Roosevelt County in northeastern Montana. Soil variations were distributed indiscriminately over the gentler and steeper slopes.

Sandier soils showed a measurably better intake of moisture than heavier classes, and there was some indication of more rapid precipitation than could be fully utilized.

Water conservation practices were effective for increasing moisture-storage efficiency, as were frequent tillage and a closer sequence of crops in a locality where summer fallowing was more often practiced for weed control than for saving moisture.

Little Muddy District, Williston, N. Dak.

Dark-brown soils of a wide range in texture, under a 13.42-inch rainfall, predominated in Little Muddy District.

Natural factors of the soil-climatic complex strongly outweighed cultural practices in determining moisture-storage efficiency. Highly significant were temperature, size of rain, coarseness of soil texture, and flatness of slope. Absence of excessive rainfall was significant. Closeness of crop sequence was highly significant. None of the other farming practices showed measurable effects on soil moisture.

Summer fallowing, which was widely practiced in this district, tended definitely to decrease moisture-storage efficiency, but here again it is recognized to be more useful in weed control than to accumulate soil moisture.

Arnegard District, Watford City, N. Dak.

Hard land soils of dark-brown color predominated in this district on slopes of 2 to 6 percent, with the exception of a minor area of sandy loam soils. Annual average rainfall was 15.87 inches.

Natural factors alone influenced moisture-storage efficiency; degree of slope more than size of rain and temperature. None of the conservation practices showed a measurable effect on soil moisture. Summer fallowing was regularly applied with good results as to moisture-storage efficiency. This area apparently represented an ideal combination of conditions for efficient use of soil-moisture storage.

Haakon District, Philip, S. Dak.

Dark-brown hard land soils of Haakon District lay on slopes of 2 to 5 percent. Average rainfall was 17.10 inches.

Warmer seasons resulted in substantially higher moisture-storage efficiency, and heavy rains were wasteful. Weed control and a close sequence of crops contributed most to moisture-storage efficiency among farming methods employed. Summer fallowing lowered moisture-storage efficiency. Fallowing was seldom used in this district.

Mona Andes District, Sidney, Mont.

In Mona Andes District a wide range of soil classes was under cultivation. They ranged from heavy silt loam to sandy loam, with slopes between 2 and 6 percent. Average rainfall was 13.83 inches.

Summer fallowing was commonly used, although closeness of crop sequence was the dominant factor in moisture-storage efficiency. Frequency of tillage and degree of water conservation practiced were also highly significant. Milder winter temperatures were favorable to soil-moisture storage, and coarseness of soil texture was negatively related.

The advantage lay with results capable of being produced by operational factors; the farmer was in a very good position to control soil-moisture storage.

Central Winter Wheat Area

Red Willow District, McCook, Nebr.

Black silty clay and silt loam soils of this district lay mainly on slopes of 1 to 3 percent. An occasional field of 4-percent slope was recorded. Average annual rainfall was 23.73 inches.

Close crop sequence and stubble mulching made highly significant contributions to moisture-storage efficiency. Coarseness of soil texture and flatness of slope favored moisture storage, but heavier rainfall was wasteful.

Summer fallowing was regularly practiced for wheat growing, although at some expense to moisture-storage efficiency.

Decatur District, Oberlin, Kans.

Black silty clay and silt loam soils on ½- to 3½-percent slopes accounted for most of the cultivated lands in Decatur District. An occasional field of 4- or 5-percent slope was encountered. Cultural practices and natural factors were about equal in determining moisture-storage efficiency. Average period rainfall was 21.83 inches.

Measurable losses of moisture occurred, owing to heavy rainfall, slow infiltration, and runoff from the steeper slopes. These soil-water relations responded well to water conservation methods, ample tillage, and a closer sequence of crops. Summer fallow was regularly practiced in this district.

Ellis District, Hays, Kans.

Black moderately heavy soils on variable slopes of ½ to 5 percent predominated in Ellis District. A few fields of sandy loam were recorded. Annual rainfall averaged 28.16 inches.

Factors of runoff from steeper slopes and waste from excessive rains were the main natural causes of low moisture efficiency. Water conservation methods, stubble mulching, and a closer sequence of crops were the farmers' most effective ways of building up moisture-storage efficiency. Summer fallowing was not so extensively practiced as in some districts farther west.

Chase District, Imperial, Nebr.

Dark-brown soils of a wide range in texture, from heavy silt loam to sand, covered the gentle slopes, ½ to 3 percent, of this western Nebraska district. Annual average rainfall was 22.80 inches.

Amount and character of rainfall influenced moisture-storage efficiency more than soil texture among the natural factors. Weed control and closer crop sequence produced significant effects upon soil-moisture storage among the farming practices applied. Summer fallowing was regularly practiced with good results for weed control, but with measurable reduction of moisture-storage efficiency.

Peetz District, Sterling, Colo.

Dark-brown soils of a wide range in texture lay on slopes of 1 to 4 percent in the Peetz District. Average annual rainfall was 15.82 inches.

Water conservation methods with a close sequence of crops were the only farming practices that showed a significant relation to moisture-storage efficiency. Among environmental factors, variations in temperature and soil texture had no measurable effect, but heavy rains or a prolonged period of wet weather reduced moisture-storage efficiency.

Summer fallowing was widely practiced to produce good wheat yields, although some reduction in soil-moisture storage was noticeable.

Haxtun-Yuma District, Yuma, Colo.

In this dark-brown soil area, textures ranged from clay loam to loamy sand. Sandier soils predominated. Slopes of cultivated land ranged from 1 to 4 percent. Rainfall averaged 17.87 inches.

Natural variables all affected moisture-storage efficiency to a significant extent. Too heavy weekly rates of rainfall were wasteful, although heavier individual rains were more efficient on these sandy soils than soils of other districts. Steeper slopes wasted moisture, and warmer temperatures where summer fallow was frequently applied lowered moisture-storage efficiency.

Water conservation practices and a closer sequence of crops were effective aids to soil-moisture storage, but natural forces strongly outweighed means at the farmer's disposal to control seasonal moisture supply.

Plainview-Smoky Hill Districts, Burlington, Colo.

Dark-brown hard lands lay mainly on slopes of 1 to 3 percent under a rainfall of 17.09 inches. Few fields of 4 to 6 percent were in cultivation.

Temperatures were negatively related to moisture-storage efficiency. Lengthening the preparatory period reduced soil-moisture storage. All other operational factors showed significant effects on moisture-storage efficiency. Water conservation methods, stubble mulching, and weed control were highly beneficial.

Summer fallowing was widely practiced at the expense of moisture-storage efficiency. Whether it was worth the expenditure as insurance against total wheat failure is uncertain, as these districts lie on the border of an area where summer fallowing did not always prevent failure.

Sherman District, Goodland, Kans.

Dark-brown hard land soils of Sherman District lay on slopes of ½ to 3 percent under a rainfall of 17.60 inches. An occasional field of 4-percent slope was recorded.

Soil texture and slope did not vary enough to influence moisture-storage efficiency. Temperature and high rate of weekly rainfall were negatively significant.

Total influence of operational factors outweighed climatic effects on moisture-storage efficiency. Water conservation practices, ample tillage, weed control, and a closer sequence of crops were all highly beneficial. Wheat yields in the 30- to 50-bushel class were harvested from summer-fallowed land 4 years—1 out of 5 (in

1949) yields averaged 20 bushels. Fallow practice here seems to provide reasonable assurance against crop failure and may be considered worth the price of reduced moisture-storage efficiency.

Scott District, Scott City, Kans.

In the dark-brown soil area of Scott District a wide range of textures occurred. Slopes ranged from ½ to 2 percent, with occasional areas of 3 and 4 percent. Rainfall averaged 23.45 inches.

Temperature and soil texture showed highly significant relations to soil-moisture storage; effect of temperature was negative, and coarseness of soil texture was positively related.

Frequency of tillage favored moisture-storage efficiency. Several wheat crop failures were recorded on summer-fallowed fields, although fallowing was accepted and used regularly during the period 1946–51. Lengthening of the preparatory period reduced moisture-storage efficiency here more than the other factors studied.

Horse-Rush District, Simla, Colo.

Brown soils of a wide range in texture on slopes of 1 to 3 percent predominated in this east-central Colorado district. A few fields of 4 and 5 percent were in cultivation. Average annual rainfall was 16.63 inches.

Water conservation methods, frequency of tillage, and closeness of crop sequence were the operational factors that showed a significant relation to moisture-storage efficiency. Rate of rainfall and slope did not vary enough to exert a measurable effect, but cooler temperatures, smaller sized rains, and coarser topsoil textures favored moisture-storage efficiency.

Summer fallow was widely practiced in this district, but it was done as much for row crops as for wheat. The record does not show that fallowing prevented crop failure, although it substantially increased the yields harvested. The extent to which the practice decreased moisture-storage efficiency was not so great as in many other central Plains locations, nor as great as the more important natural variables studied.

Cheyenne District, Cheyenne Wells, Colo.

In the Cheyenne District a wide range of brown soils lay on slopes of 1 to 4 percent. Average annual rainfall was 17.10 inches.

Rapid evaporation from high temperatures and dry atmosphere, along with an occasional excessive rainfall, contributed to lowering of moisture-storage efficiency. Water conservation methods and stubble mulching showed favorable results, as did effective weed control with a minimum of tillage.

Summer fallowing was regularly used, but it did not insure against failure. In this one district, effect of closer crop sequence upon moisture-storage efficiency was not statistically significant.

Southern Winter Wheat Area

Canadian District, Tucumcari, N. Mex.

Brown soils of sandy textures on slopes of ½ to 2½ percent predominated in the Canadian District. Average annual rainfall was 14.51 inches.

Operational variables did not show significant relations to moisture-storage efficiency, except those for closer sequence of cropping and water conservation. Water conservation practices variable was negative in this sandy soils area.

Among natural variables, amount of rainfall, excessive-type showers, and higher temperatures substantially reduced soil-moisture storage. Soils of most receptive efficiency occupied the steeper slopes up to 2½ percent.

Summer fallowing was sparingly used and with uncertain results. It did not insure against crop failure.

Quay District, Tucumcari, N. Mex.

Brown soils in a wide range of texture made up the cultivated area of the Quay District. Herein is the flattest land recorded in the Great Plains for an area the size of a soil conservation district. Slopes of 1 to 1½ percent predominated, with only an occasional field of 2 percent. Rainfall averaged 13.81 inches.

Lighter soils, though on slightly steeper slopes, substantially increased moisture-storage efficiency. Depressing effect of warmer temperatures was greater here than elsewhere in the central or southern Plains areas. Size of rain was highly significant. Weed control and closeness of crop sequence were the only farming practices that significantly aided moisture-storage efficiency.

Summer fallowing was widely and regularly practiced in preparation for wheat, and, although it did not insure against failure 2 years out of 5, yields were fairly consistent when it was successful.

Curry District, Clovis, N. Mex.

Cultivated lands consisted of a wide range of textures of brown soils lying on slopes of ½ to 1½ percent. Average annual rainfall was 15.30 inches.

All natural variables, excepting land slope, showed significant relations to moisture-storage efficiency, in keeping with surrounding districts.

Closeness of crop sequence was the most important management factor of operational significance to soil-moisture storage. Weed control was associated with stubble-mulch practice negatively, which more than offset any beneficial effects of crop residues. None of the other practices had a significant relation to moisture-storage efficiency.

Summer fallowing was regularly practiced, but it did not insure against crop failure in this dis-

trict. In good seasons summer fallow yields ranged generally between 15 and 30 bushels per acre. In the worst years frequency of failure was almost as great as on continuously cropped land.

Texas District, Guymon, Okla.

In this brown-soil district, silty clay loams predominated. Most cultivated land lay on slopes of ¾ to 2½ percent. An occasional field up to 4½ percent was encountered. Average annual rainfall was 20.64 inches.

Natural factors that strongly reduced moisture-storage efficiency were higher temperatures and frequent excessive rainfall. Land slope variation was not great enough to influence the relationship.

Degree of stubble mulching was significantly correlated with weediness, resulting in a depressing effect on moisture-storage efficiency. Closeness of crop sequence contributed most to moisture efficiency in this border area district.

Summer fallowing was not widely practiced, nor did it prevent crop failure when practiced.

Beaver District, Beaver, Okla.

Brown soils of Beaver District ranged from clay loam to loamy sand in topsoil texture and from ¾ to 4 percent in slope. An occasional field ran as high as 5- or 6-percent slope. Average annual rainfall was 22.16 inches.

Along with the adjoining district of Lipscomb in Texas and the similar area of Quay District, N. Mex., which have in common striking contrasts between flat and rolling topographies, Beaver District showed a positive relation between slope and moisture-storage efficiency. There was a marked tendency throughout marginal parts of the Great Plains for farmers to put off until last the breaking out of steeper slopes; and much plowing of steep slopes occurred during the war years of the 1940's. It is worth mentioning that newness of marginal soils wears off rapidly, and these reverse relationships may not be expected to last long if such fields remain in cultivation.

Closeness of crop sequence was the only farming practice registering a significant relationship in the Beaver District. Summer fallowing was rarely used, and then with indifferent results.

Ochiltree District, Perryton, Tex.

Cultivated lands of this brown soil district occurred in a wide range of textures on slopes of ¾ to 5 percent. Average annual rainfall was 23.26 inches.

Variation in temperature influenced moisture-storage efficiency more than any other factor. High temperature depressed the efficiency. Lengthening the preparatory period was a close second in importance in reducing efficiency. Neglect of tillage and steepness of slope recorded significant effects also.

Use of summer fallowing slightly increased wheat yields, but it was not regularly or extensively practiced.

Lipscomb District, Higgins, Tex.

Brown soils of Lipscomb District occurred in a wide range of topsoil textures on slopes of ¾ to 4 percent, with a very few soils of 5-percent slope. Average annual rainfall was 23.89 inches.

All factors in the natural category excepting slope were highly significant in their effects on moisture-storage efficiency. Soil slope was positively correlated, as explained under Beaver District, which adjoins Lipscomb on the north.

Temperature and excessive rainfall during short periods were strongly related to moisture wastefulness. Closeness of crop sequence was the most important operational factor favoring greater moisture-storage efficiency.

Summer fallowing was not regularly practiced in this district.

Deaf Smith District, Hereford, Tex.

Brown soils of this hard lands district lay mainly on slopes of ½ to 1½ percent. Maximum slope encountered in a very few cases was 2 percent. Average annual rainfall was 18.48 inches.

Drying temperatures on the natural side and lengthening the preparatory period on the operational side were dominant factors restricting soil-moisture storage. Measurable wastes took place through periods of heavy rainfall. Runoff and erosion were partially offset by use of water conservation methods and frequent tillage.

Summer fallowing was used regularly but not extensively. It did not prevent crop failure 2 years out of 5. However, fairly heavy yields (in the 30- to 40-bushel class) were harvested in more favorable seasons.

Castro District, Dimmitt, Tex.

Brown soils of this hard lands district lay on slopes of ½ to 1½ percent. Average annual rainfall was 19.50 inches.

Slope, as in Deaf Smith District adjoining Castro on the north, did not vary enough to affect moisture-storage efficiency. High temperatures and heavy rainfall were factors of waste. Results of water conservation methods were excellent, and closeness of crop sequence also proved important.

Summer fallowing did not insure against failure 2 years out of 5. It was not widely practiced.

Briscoe District, Silverton, Tex.

Brown soils of this hard lands district lay mainly on slopes of ½ to 1½ percent. An occasional extreme of 2 or 2½ percent was recorded. Average annual rainfall was 22.45 inches.

Variation in slope was not sufficient to affect moisture-storage efficiency. Medium-textured soils were distinctly more efficient than clay loams. Frequent tillage and close crop sequence were the

operational factors that proved highly significant in relation to moisture-storage efficiency.

A small amount of summer fallowing was regularly practiced. It failed 1 year out of 5 to insure a yield.

Hale District, Plainview, Tex.

The brown soil of the hard lands of Hale District lay on slopes of ½ to 2 percent under an average rainfall of 20.02 inches.

There was not enough variation in texture or slope for either to affect moisture-storage efficiency. Temperature, amount of rainfall, and size of rains were negatively related.

Water conservation methods were effective, along with weed control and closeness of crop sequence.

Summer fallowing did not greatly increase crop yield and was not regularly nor widely practiced.

Floyd District, Floydada, Tex.

Brown hard land soils ranged from ½ to 3 percent in slope in this Texas High Plains District. Average annual rainfall was 18.67 inches.

Variations in soil textures and slopes were not great enough to make big differences in moisture-storage efficiency. Amount of rainfall and seasonal variations in temperature were the natural factors that affected soil-moisture storage.

On the operational side water conservation methods, frequency of tillage, and closeness of crop sequence showed beneficial relations.

Summer fallowing did not produce outstanding results and was not widely used.

Dewey District, Seiling, Okla.

A wide range of textures was found in this reddish-brown soil area, where slopes ranged between ¾ and 4 percent. However, a few fields were recorded on slopes of 5 to 7 percent. Average annual rainfall was 24.56 inches. The landscape would be recognized as rolling topography.

Temperature and amount of rainfall were dominant factors in soil-moisture wastage. On the operational side, only weed control and closeness of crop sequence showed a strong effect on moisture-storage efficiency.

Summer fallowing very rarely occurred during the 5-year period of observation in this district.

Ellis District, Shattuck, Okla.

Cultivated lands of Ellis District included brown soils, clay loam to sandy loam in texture, on slopes of 1 to 4 percent. Average annual rainfall was 21.86 inches.

Dominant factors in control of moisture-storage efficiency were variations in land slope, temperature, and amount of weekly rainfall.

Soil and water conservation methods attempted had a negative effect on moisture-storage efficiency. Excessive tillage measurably reduced efficiency, but apparently controlled weeds to the extent that variation in weed growth was not a significant factor. Of the operational factors recorded, closeness of crop sequence had the most effect in building up moisture-storage efficiency.

Summer fallow was not widely nor regularly employed.

Duck Creek District, Spur, Tex.

A wide range of textures was found in the reddish-brown soil area of Duck Creek District, where slopes ranged from ½ to 2½ percent. Average annual rainfall was 21.81 inches.

Evaporation waste associated with high temperatures depressed moisture efficiency more than any other factor. Lengthening of preparatory period was next in wastefulness. In a community where amount of tillage ranged from meager to moderate, the moderate volume of soil stirred increased moisture-storage efficiency. Sandier types consistently stood higher in efficiency.

Summer fallowing was not used in this district.

Two Buttes-Bent District, Two Buttes, Colo.

A wide range of soil texture was found in the light-brown soil area of Two Buttes-Bent District, where land slopes ranged from 1 to 3 percent. Average annual rainfall was 16.80 inches.

Amount of weekly rainfall, fineness of soil texture, and steeper slopes were natural factors that depressed moisture-storage efficiency most. Warm temperatures and large rains also detracted measurably.

Water conservation measures, stubble mulch, and a closer crop sequence aided soil-moisture storage, while unnecessary tillage was wasteful of moisture as well as labor.

Summer fallowing produced good yields in favorable seasons but resulted, along with continuous cropping, in a high percentage of failures 2 years out of 5.

West Baca District, Springfield, Colo.

West Baca District contained a wide range of textures of light-brown soils on slopes of 1 to 3 percent. Average annual rainfall was 17.38 inches.

Variation in slope fell short of significance in determining moisture-storage efficiency, but sandier soils were measurably more efficient than heavier soils. Temperature was the dominant factor in moisture wastefulness.

Effect of water conservation practices was highly significant, as were closeness of crop sequence and ample tillage.

Summer fallowing produced good yields in favorable seasons but generally failed 2 years out of 5. Fallowing could not insure a small yield or even a ground cover in unfavorable seasons.

Northeastern District, Clayton, N. Mex.

Light-brown soils of a wide range in texture lay on slopes of ¾ to 3 percent under an average annual rainfall of 16.79 inches in the Northeastern District.

Variation in weekly rate of rainfall was the most potent factor affecting moisture-storage efficiency. Size of rain and coarseness of soil texture also imposed a measurable influence. Of operational factors, effect of stubble mulch and closeness of crop sequence were highly significant.

During the period 1946–51 the record of summer fallow yields was not much better than that of wheat in continuous culture.

Mesa-Colfax District, Mosquero, N. Mex.

Cultivated lands of the Mesa-Colfax District consisted of light-brown soils of a wide range of textures on slopes of 1 to 2½ percent. Average annual rainfall was 13.22 inches.

High temperature was the most effective natural condition depressing moisture-storage efficiency. Lengthening of preparatory period was a close second. Other factors highly significant in detracting from moisture efficiency were size of rain, fineness of soil texture, and neglecting to use stubble mulching.

Summer fallowing was widely practiced, but it did not insure against failure. Summer fallow yields were not markedly higher than continuous culture where wheat followed wheat that had been a normal failure.

Roosevelt District, Portales, N. Mex.

Sandy soils predominated in the light-brown soils of Roosevelt District, with slopes of cultivated fields running ½ to 2 percent. Average annual rainfall was 16.03 inches.

Coarseness of topsoil texture and small rains at a not excessive weekly rate favored moisture-storage efficiency. Only stubble mulching among conservation practices was highly significant. The effect was negative on soil-moisture storage.

Summer fallowing was not systematically followed, and wheat yields were not greatly higher than those harvested from continuously cropped land.

OPERATIONAL METHODS THAT SHOW PROMISE

In an area where drought is accepted as one of the natural conditions, farmers recognize that timing of the interval and duration of wet and dry periods are largely unpredictable. Therefore, the one reliable guide available to them is the actual progress of soil-moisture accumulation from one crop to the next. A general guide available to dryland operators is seasonal expectation obtained from weather records.

To make the best use of higher moisture-storage efficiency by closer crop sequence does not always mean to choose crop sequences in which each crop followed the previous one as closely as possible. It does mean farmers should plant a productive adapted crop as soon as practicable after a promising supply of soil moisture has accumulated. In many localities soil moisture accumulated by summer fallowing has proved to be profitable. On rare occasions it may prove wasteful to summer-fallow a wheatfield if unexpected rains have provided sufficient initial moisture to start the next crop a year sooner than planned.

When tempted to change to different types of crops to take earlier advantage of soil moisture, operators should carefully compare productivity and profitability of the contemplated change with that to be expected from standard operation when a regular crop is planted at the usual time.

Another practice for which a price must sometimes be paid is stubble mulching. When relatively large amounts of the previous crop's residue were left on the surface at the end of the preparation period, moisture-storage efficiency was favorably affected in several districts. However, the extra expense of special tillage along with the risk of weed growth may make stubble mulching in certain districts a choice that depends more on the need for erosion control than for soil-moisture efficiency. Where stubble mulching does not create a difficult weed problem, it may sometimes be recommended for both soil-moisture storage and erosion control.

Weed control is usually a moisture-saving practice. When tillage becomes necessary to keep weeds down, timeliness of the operation is likely to determine largely its relative effectiveness. Considerable mechanical skill and experience with climatic conditions are necessary to determine the most effective time to cultivate for weed control. For moisture saving, the ideal time to kill weeds is when they are small. When a very scattered or thin stand of weeds start in small-grain stubble, whether to cultivate often presents a difficult decision for the farmer.

Leaving stubble or stalks standing through the winter may serve the twofold purpose of moisture conservation and erosion control. Considered apart from crop residues in general, the value of stubble decreases in areas of less winter snowfall.

Water-conservation practices must be carefully considered in respect to local conditions. Terracing and contour tillage save water on any slope where water runs off. However, these practices have not taken hold in many Plains districts, unless there is an urgent need to protect the soil from sheet and gully erosion. Contour tillage has frequently been effective on gentle slopes where stripcropping proved inconvenient.

Deep plowing to turn up soil under shifting loose sand and deep chiseling to break up hardpans have application to water storage relations of some soils under very special conditions. Experimental results under comparable conditions are probably the best guide to such practices.

SUMMARY AND CONCLUSIONS

This study evaluates certain naturally occurring and farm operational factors affecting moisture-storage efficiency during the interval between crops in 44 soil conservation districts under dryfarming conditions in the Great Plains during the crop years 1947–51. Records collected included total amount and character of rainfall; temperature; soil characteristics (texture, slope, color); previous crop; residues; weeds; length of period between crops, tillage, and other miscellaneous soil, crop, and climatic data.

Mean temperature variation had little effect on efficiency of moisture storage from southern South Dakota across Nebraska into northern Kansas. North of this area warmer temperatures generally increased moisture-storage efficiency; south of this area warmer temperatures generally decreased moisture-storage efficiency. Temperature variation was one of the dominant factors related to moisture-storage efficiency in the southern Plains.

The effect of rainfall per week during the period between crops on moisture-storage efficiency was consistently negative. In only 9 districts out of 44 was the standard partial regression coefficient nonsignificant.

Average amount of precipitation per rainy day showed a significant negative relation to moisture-storage efficiency in 17 of 44 instances. In four cases the maximum precipitation per rainy day resulted in significant positive values.

Topsoil texture significantly affected moisture-storage efficiency. Moisture-storage efficiency was highest on sandy soils of the central and southern Plains. In the northern area, the high surface-soil content of organic matter of black and dark-brown soils was a dominant factor in moisture-storage efficiency.

Slope of the land was not one of the more important factors affecting moisture-storage efficiency, but what relationship that did exist was predominantly negative.

Among the several farming practices available to farmers to combat drought, water conservation practices provided better-than-average effects in the central area. Negative results were recorded in 2 of the southern districts, but 19 significant positive effects of water conservation were found.

Stubble mulching, as practiced by the average farmer, did not substantially affect moisture-storage efficiency. It usually was used as an erosion-prevention practice.

Volume of soil stirred in preparatory tillage operations did not statistically affect moisture-storage efficiency in 23 out of 44 districts.

Weed growth generally depressed moisture-storage efficiency, but only 13 districts showed a significant negative relationship.

Placing management of crops foremost is not the usual practice in dryland agriculture. Devising a close crop sequence would be secondary to such considerations as mechanical convenience and labor budgeting. Nevertheless, length of period between crops proved to be the most powerful and consistent factor studied in its effect on moisture-storage efficiency. Lengthening the preparatory period decreased moisture-storage efficiency to a highly significant extent in 41 out of 44 districts.

Although variation in natural conditions resulted in 129 cases of significant effect on soil-moisture efficiency to 112 for operational factors, the sum of relative weights of the operational factors as compared to that for natural conditions was 20.9 to 18.3. Hence, it may be concluded that moisture-storage efficiency can be influenced substantially as much by the operational factors selected by the farmer as by the natural variations in seasonal and soil conditions.

APPENDIX

Table 3.—*List of factors under study in dryfarming areas of the Great Plains for the crop years 1947–51, with designated code*

Code [1]	Factor	Measurement, code, or rating
Al	Altitude	Feet above sea level by 100-foot intervals.
*C**	Water conservation practices	Degree of intensity index.
	Tillage—	
*D**	By all methods	Sum of inches of soil stirred.
DCh	By chisel implement	Do.
DCu	By cultivator	Do.
DD	By disk	Do.
DM	By moldboard plow	Do.
TI	Interval	Average number of weeks.
EA	Soil erosion accumulations	Soil Conservation Service rating by degrees of severity.
ER	Soil erosion removals	Do.
*L**	Length of preparatory period	Weeks.
La	Latitude	Degrees N.
LC	Land capability	Soil Conservation Service rating numbers as a code.
*M**	Stubble mulch	Amount left at seed time (visual rating).
ME	Moisture-storage efficiency	Inches per inch of precipitation
	Precipitation:	
*I**	Rain per rainy day	Inches.
P	All precipitation between crops.	Do.
TR	Total rainfall during preparatory period.	Do.
WP	Frostbound period precipitation.	Do.
*WR**	Weekly rain during preparatory period.	Do.
*S**	Steepness of slope	Percent.
*ST**	Soil texture	Code: 1=clay to 7=sand.
*T**	Temperature, mean for preparatory period.	Degrees F. by 10° intervals.
TC	Topsoil color	Code: 1=light brown to 5=black.
*W**	Weed growth during preparatory period.	Rating: 1=little or none to 4=heavy.

[1] Those with asterisks are the variables discussed in relation to moisture-storage efficiency.

Table 4.—*Simple correlation coefficients (r) relating moisture-storage efficiency to 10 natural or operational factors in the Great Plains, 1946–51*

Northern Spring Wheat Area

Soil conservation district and State	Simple correlation coefficients: Natural factors [1] T	WR	I	ST	S	Operational factors [1] C	M	D	W	L	Observations	Least significant values: 5-percent level	1-percent level
											Number		
Two Creeks, N. Dak.	−0.340	−0.334	−0.286	0.116	−0.220	0.335	0.219	−0.292	−0.065	−0.436	187	0.145	0.186
Hamill, S. Dak.	−.188	−.421	−.426	−.008	.002	.260	.286	−.223	−.224	−.555	561	.083	.110
Clearfield, S. Dak.	−.318	−.578	−.493	.036	.074	.261	.273	−.441	−.264	−.748	414	.098	.128
American Creek, S. Dak.	.115	−.439	−.372	.047	−.007	.263	.201	−.281	−.153	−.515	500	.088	.115
Brule, S. Dak.	−.433	−.099	−.218	−.043	.099	.522	.352	−.411	−.551	−.547	674	.082	.110
Redfield, S. Dak.	−.022	−.439	−.074	−.001	.165	.053	.219	−.289	−.188	−.388	663	.075	.097
Beadle, S. Dak.	.097	−.343	.044	.091	.022	.263	.264	−.213	−.126	−.481	540	.087	.113
Reserve, Mont.	−.034	−.160	−.053	.120	−.080	.127	.161	−.136	−.004	−.244	246	.125	.164
Culbertson, Mont.	−.137	−.247	−.069	.265	−.108	.282	.203	−.201	−.055	−.289	379	.102	.134
Little Muddy, N. Dak.	.195	−.209	−.058	.255	−.420	−.024	.112	−.054	.086	−.183	195	.138	.181
Arnegard, N. Dak.	.126	−.083	.152	.121	.241	.116	−.084	−.029	.090	−.036	200	.138	.181
Haakon, S. Dak.	.025	−.083	−.174	.038	−.047	.120	.127	−.061	−.076	−.158	517	.115	.188
Mona Andes, Mont.	.029	−.203	−.108	−.105	−.002	.229	.263	−.081	−.070	−.225	208	.138	.181

Central Winter Wheat Area

Soil conservation district and State	T	WR	I	ST	S	C	M	D	W	L	Observations	5-percent level	1-percent level
Red Willow, Nebr.	−0.168	−0.339	−0.207	0.346	−0.254	−0.119	0.192	−0.225	−0.087	−0.462	397	0.128	0.198
Decatur, Kans.	−.203	−.407	−.273	.226	−.181	.176	.146	−.340	−.199	−.497	319	.110	.147
Ellis, Kans.	.196	−.314	−.213	.067	−.142	.091	.282	−.206	−.167	−.456	442	.093	.122
Chase, Nebr.	−.113	−.435	−.292	.087	.040	.046	.088	−.333	−.085	−.508	426	.097	.125
Peetz, Colo.	−.257	−.440	−.417	.024	.035	.120	.089	−.216	−.059	−.340	467	.092	.120
Haxtun-Yuma, Colo.	−.376	−.392	−.277	.272	.000	.187	.300	−.341	.052	−.444	216	.138	.181
Plainview, Colo.	−.254	−.309	−.225	.013	.019	.210	.257	−.349	−.121	−.360	1,014	.062	.081
Sherman, Kans.	−.358	−.328	−.204	.019	.003	.186	.053	−.263	−.186	−.392	608	.082	.110
Scott, Kans.	−.278	−.343	−.168	.173	.035	.082	.048	−.132	−.130	−.341	368	.104	.140
Horse-Rush, Colo.	−.408	−.264	−.243	.259	.064	.160	.008	−.157	−.101	−.147	467	.092	.118
Cheyenne, Colo.	−.151	−.385	−.234	.026	−.013	.175	.197	−.288	−.071	−.179	395	.098	.128

Southern Winter Wheat Area

Soil conservation district and State	T	WR	I	ST	S	C	M	D	W	L	Observations	5-percent level	1-percent level
Canadian, N. Mex.	−0.341	−0.427	−0.264	0.068	−0.045	−0.037	0.073	−0.180	0.056	0.268	380	0.102	0.134
Quay, N. Mex.	−.369	−.266	−.336	.296	.080	.021	.125	−.089	.005	.092	328	.108	.145
Curry, N. Mex.	−.547	−.607	−.436	.372	.141	−.035	.218	−.265	.013	.266	836	.068	.089
Texas County, Okla.	−.083	−.200	−.145	.088	.013	.007	.126	−.067	−.055	−.160	312	.110	.146
Beaver County, Okla.	.047	−.153	−.143	.032	.148	.143	.057	.043	−.095	−.158	348	.106	.140
Ochiltree, Tex.	−.163	−.070	−.041	−.075	−.192	−.078	.022	.130	−.100	−.078	511	.088	.115
Lipscomb, Tex.	−.276	−.342	−.156	.162	.162	−.043	.032	−.149	.003	.023	326	.109	.145
Deaf Smith, Tex.	−.215	−.183	−.242	−.021	−.004	.202	.112	.011	−.070	−.149	255	.126	.166
Castro, Tex.	−.224	−.271	−.270	.007	−.042	.425	.086	−.148	−.135	−.091	247	.126	.166
Briscoe, Tex.	−.292	−.126	−.166	.179	.109	.070	.120	−.089	−.130	−.249	214	.135	.176
Hale, Tex.	−.333	.347	−.335	−.078	−.153	.346	.243	−.182	−.309	−.168	294	.115	.153
Floyd, Tex.	−.256	−.405	−.329	−.039	.107	.184	.195	−.011	−.241	−.187	322	.109	.146
Dewey, Okla.	−.043	−.117	−.010	.016	−.138	−.001	−.010	.016	−.177	−.144	354	.107	.140
Ellis, Okla.	−.080	−.233	−.230	.073	−.782	−.149	.025	−.059	−.153	−.139	355	.107	.140
Duck Creek, Tex.	−.335	.041	.114	.174	−.036	−.015	.013	.001	−.032	−.033	195	.140	.183
Two Buttes-Bent, Colo.	−.207	−.491	−.264	.452	.009	.269	.245	−.420	.182	−.276	330	.108	.145
West Baca, Colo.	−.314	−.310	−.216	.378	−.042	.319	.031	.040	−.101	.167	332	.108	.145
Northeastern, N. Mex.	−.341	−.539	−.304	.176	.051	.140	.287	−.160	−.125	.285	321	.109	.146
Mesa-Colfax, N. Mex.	−.312	−.275	−.247	.210	−.018	.068	.029	−.017	−.068	.126	523	.188	.115
Roosevelt, N. Mex.	−.317	−.457	−.255	.394	.341	−.042	.080	−.405	.031	.324	494	.090	.117

[1] T=Mean temperature of preparatory period.
WR=Mean rainfall per week.
I=Average rainfall per rainy day.
ST=Surface soil texture (code).
S=Land slope (percent).
C=Water conservation practices (code).
M=Amount of stubble mulch preserved.
D=Total soil stirred.
W=Weed growth permitted.
L=Length of preparatory period.

Table 5.—*Standard partial regression coefficients for factors affecting moisture-storage efficiency, mean moisture efficiency, and multiple regression coefficients for the Great Plains, 1946–51*

Northern Spring Wheat Area

Soil conservation district and State	Standard partial regression coefficients [1]										Mean moisture efficiency	Observations	Multiple correlation coefficient
	Natural factors [2]					Operational factors [2]							
	T	*WR*	*I*	*ST*	*S*	*C*	*M*	*D*	*W*	*L*			
												Number	
Two Creeks, N. Dak.	−0.104	−0.183	−0.069	0.120	−0.218**	0.035	0	0.173	−0.122	−0.429**	5.60	187	0.578
Hamill, S. Dak.	−.074	−.242**	−.271**	−.075*	−.005	.159**	.031	.224**	−.064	−.453**	3.78	561	.706
Clearfield, S. Dak.	.025	−.230**	−.203**	.086**	.092**	.061	−.118**	.035	.022	−.602**	3.91	414	.802
American Creek, S. Dak.	.101*	−.235**	−.262**	−.226**	−.201**	.031	.089	.045	−.132**	−.455**	4.30	500	.681
Buffalo-Brule, S. Dak.	−.156**	−.119**	−.166**	.046	.137**	.266**	.096**	.138**	−.390**	−.226**	3.15	674	.763
Redfield, S. Dak.	.223**	−.443**	−.018	.103**	.160**	−.022	.109**	−.021	−.121**	−.508**	3.09	663	.683
Beadle, S. Dak.	.120**	−.350**	−.016	.143**	−.106*	.124**	.179**	.230**	−.096*	−.490**	3.44	540	.648
Reserve, Mont.	−.050	−.254**	.163	.105	−.046	.084	.056	.263*	−.016	−.334**	5.42	246	.339
Culbertson, Mont.	.051	−.240**	.088	.275**	−.018	.154*	.089	.237*	−.097	−.285**	6.97	379	.472
Little Muddy, N. Dak.	.296**	−.171*	.206**	.395**	−.544**	.044	.057	.164	.034	−.445**	5.59	195	.701
Arnegard, N. Dak.	.192*	−.132	.190*	.091	.197**	.122	−.084	−.084	.049	.011	4.46	200	.388
Haakon, S. Dak.	.223**	.103	−.106*	−.007	−.050	.065	.071	.020	−.158**	−.273**	2.61	517	.337
Mona Andes, Mont.	.247**	−.040	−.006	−.516**	.098	.284**	−.003	.581**	−.066	−.872**	5.57	208	.536
Central Winter Wheat Area													
Red Willow, Nebr.	0.078	−0.314**	−0.045	0.300**	−0.093*	−0.028	0.140**	0.037	−0.021	−0.420**	3.66	397	0.670
Decatur, Kans.	−.096	−.358**	−.019	.110**	−.105*	.145**	.081	.147*	−.066	−.530**	3.68	319	.692
Ellis, Kans.	.078	−.369**	−.067	.046	−.143**	.146**	.083*	.069	−.059	−.467**	3.52	442	.644
Chase, Nebr.	.086	−.263**	−.170**	.136**	.018	.063	.029	−.027	−.098*	−.473**	4.55	426	.656
Peetz, Colo.	−.069	−.271**	−.166**	.061	−.007	.097*	.038	.054	.061	−.226**	3.80	467	.540
Haxtun-Yuma, Colo.	−.192*	−.261**	.206*	.313**	−.161**	.143*	.111	.060	−.029	−.376**	3.43	216	.638
Plainview-Smoky Hill, Colo.	−.158**	−.176**	−.036	.018	−.022	.125**	.116**	−.076*	−.197**	−.313**	3.47	1,014	.567
Sherman, Kans.	−.297**	−.147**	−.057	.008	−.041	.173**	−.017	.145**	−.100**	−.551**	3.97	608	.628
Scott, Kans.	−.358**	−.040	−.123	.180**	−.047	.047	.018	.129*	−.084	−.467**	3.25	368	.567
Horse-Rush, Colo.	−.378**	.076	−.196**	.226**	−.003	.110**	−.018	.108*	−.007	−.221**	3.29	467	.523
Cheyenne, Colo.	.172**	−.401**	−.052	.069	−.009	.092*	.153**	−.260**	−.122**	−.080	3.07	395	.535
Southern Winter Wheat Area													
Canadian, N. Mex.	−0.447**	−0.410**	−0.140**	−0.059	0.143**	−0.132**	−0.085	−0.086	−0.039	−0.363**	7.52	380	0.518
Quay, N. Mex.	−.739**	.100	−.272**	.279**	.261**	−.087	.025	.082	−.114*	−.476**	3.48	328	.625
Curry, N. Mex.	−.521**	−.498**	−.075*	.178**	.006	−.034	−.101**	.051	−.086**	−.474**	5.22	836	.725
Texas, Okla.	−.596**	−.331**	.036	.013	−.092	−.021	−.145*	.109	−.042	−.728**	4.17	312	.451
Beaver, Okla.	.081	.271**	−.027	.042	.137*	.083	.038	.070	−.018	−.241**	4.20	348	.357
Ochiltree, Tex.	−.690**	−.111*	−.033	.039	−.257**	.013	.001	.274**	−.021	−.629**	2.86	511	.504
Lipscomb, Tex.	−.569**	−.561**	−.227**	.148**	.113*	.021	−.031	.193**	.112*	−.655**	3.69	326	.557
Deaf Smith, Tex.	−.491**	−.184*	−.061	.060	−.103	.173**	.069	.258**	.021	−.539**	2.34	255	.526
Castro, Tex.	−.180*	−.210*	−.129	−.019	−.108	−.330**	−.105	.050	−.007	−.385**	3.25	247	.544
Briscoe, Tex.	−.592**	−.229*	−.021	.141*	.029	.015	.033	.213**	−.071	−.726**	2.60	214	.640
Hale, Tex.	−.321**	−.200**	−.130*	−.034	.043	.262**	.086	.103	−.167**	−.472**	2.61	294	.663
Floyd, Tex.	−.165**	−.460**	.011	.032	.079	.131**	.081	−.189**	−.065	−.406**	3.03	322	.601
Dewey, Okla.	−.372**	−.244**	.016	.018	−.084	.033	−.006	.111	−.185**	−.466**	3.60	354	.397
Ellis, Okla.	−.435**	−.244**	−.011	−.006	−.861**	−.071**	−.089**	−.133**	−.023	−.456**	3.25	355	.922
Duck Creek, Tex.	−.731**	.091	.117	.165*	−.055	.027	−.018	.236**	−.070	−.453**	2.75	195	.557
Two Buttes-Bent, Colo.	.122*	−.385**	−.095*	.320**	−.141**	.093*	.131**	−.119*	.063	−.174**	3.63	330	.706
West Baca, Colo.	−.498**	.012	−.259**	.198**	−.086	.161**	.018	.263**	−.066	−.266**	3.11	332	.559
Northeastern, N. Mex.	−.054	−.657**	−.110*	.106*	−.014	−.018	.194**	.022	−.064	−.326**	6.33	321	.624
Mesa-Colfax, N. Mex.	−.494**	−.111	−.168**	.154**	−.004	.053	.153**	.092	−.039	−.410**	3.99	523	.464
Roosevelt, N. Mex.	.088	−.330**	−.139**	.255**	.092	−.068	−.128**	−.113	−.073	−.020	5.39	494	.565

[1] *Indicates significance at 5-percent level; **indicates significance at 1-percent level.

[2] *T*=mean temperature of preparatory period; *WR*=mean rainfall per week; *I*=average rainfall per rainy day; *ST*=surface soil texture (code); *S*=land slope; *C*=degree of water conservation practiced; *M*=amount of stubble mulch preserved; *D*=total soil stirred; *W*=weed growth permitted; *L*=length of preparatory period.

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